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Delivering developing country growth: A new mechanistic approach driven by the photovoltaic industry

A.S. Bahaj *

The University of Southampton, Sustainable Energy Research Group, School of Civil Engineering and the Environment, Southampton SO17 1BJ, United Kingdom

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ABSTRACT

Energy security, climate change and economic crises are currently dominating the attention of the world. It is also well known that access to energy is a crucial and enabling mechanism for development. In particular, the provision of electricity in rural settings has tremendous impact on well being, education and health, especially in poorer regions in the world. In today's climate, we should, therefore, not forget the plight of those less well-off, especially in the near term due to a likely rise in protectionist policies of developed nations. In an effort to bring a balance, we need to be more diligent in our understanding of the needy, by bringing in clear objectives for development coupled with social responsibility that are likely to generate both stability and economic growth globally. Photovoltaics (PV), the conversion of sunlight to electricity, has over many decades been recognised as one of the most flexible technologies that could best benefit people in rural and deprived areas around the world. Unlike the utilisation of PV in buildings which is mainly a response to feed-in tariffs in developed countries, rural electrification offers a unique opportunity as it is less complex when compared to other renewables, but will require high levels of quality control. After the major strides made by the PV industry, it is now time for this now highly developed PV industry not only to call the shots in initiating a new approach of "PV for Development" but also to entice such entities as the G8, the UN, the EU and the World Bank to contribute to a major activity to provide electricity for the poor. This article attempts to convey a new approach to establishing such an activity. The analysis starts by considering a PV industry contribution of "one watt per kWp" manufactured to an industry trust. When combined with double contributions from the G8 countries, this will result in the provision of around 3–10 GWp of PV driven electricity for rural areas by 2020. It could be activated and owned by the PV industry alone resulting from 3.5 GWp by 2020. Receiving global approval by many of the developed countries and international institutions is more than likely to double this figure.

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* Tel.: +44 23 80592051; fax: +44 23 80677519.
E-mail address: A.S.Bahaj@soton.ac.uk.

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1. Introduction

In an era where energy security, climate change and economic crises are dominant in the news, the plight of those less well-off is likely to be marginalised, especially in the near term due to a likely rise in protectionist policies of developed nations. In an effort to bring a balance, we need to be more diligent in our understanding of the needy, by bringing in clear objectives for development coupled with social responsibility that are likely to generate both stability and economic growth globally.

It is well known that access to energy is a crucial and enabling mechanism for development [1,2]. In particular, the provision of electricity in rural settings has tremendous impact on well being, education and health. Photovoltaics (PV), the conversion of sunlight to electricity, has over many decades been recognised as one of the most flexible and less complex technology that could best benefit people in rural and deprived areas around the world. In the past many attempts have been made to develop a PV driven approach to providing rural electrification which have sadly achieved very little in terms of the goals of development—especially those highlighted by UN and known as the Millennium Development Goals (MDG) [2]. In September 2008, World leaders attended a high level event in New York to renew commitments to achieving the Millennium Development Goals by 2015 and to set out concrete plans and practical steps for action [2]. It remains to be seen whether any progress can be made to attain these goals. However, an initiative such as that promoted here could help in the provision of electricity which is central to the development of many in poorer regions in the world. In addition, there appears to be some reluctance in many global policy and government circles to take "energy for development" forward, in spite of many attempts at the various G8 meetings, most recent to consider this issue has been in Germany in June 2007 [3].

The premise that we need a 3rd industrial revolution driven by renewable energy with solar PV at its core is extremely worthwhile [4]. However, such a revolution will need to have at its centre the aspiration of the developing world. It should be socially responsible to take into account the development options needed for 1.6 billion people around the world which, in itself, could at least augment this needed 3rd industrial revolution or perhaps spark it globally.

Over the last 10 years, the PV industry has seen an unprecedented growth in both manufacturing of modules and system installations. The first has seen approximately 40% year-on-year growth; with the 2008 module shipment estimated to be around 4 GWp. The latter was a response to the many feed-in tariffs that have mushroomed around the developed world. However, the PV industry has as yet to appreciate and recognise the potential of proposing and owning an initiative or a scheme that will fulfil the utilisation of PV electricity for development. The PV industry needs to lay out a compelling social responsibility action plan to deliver electricity to the most needy people around the world. There is no doubt that in many PV industry circles such responsibility already exist, and stems from its core communal desire to deliver development through sustainable sources of energy—such as solar energy driven photovoltaic systems. Previous attempt have highlighted such needs with unfortunately little success [5].

Unlike the utilisation of PV in buildings [6,7] (see Fig. 1 for an example installation) which is mainly a response to feed-in tariffs (FITs) in developed countries, rural electrification offers a unique opportunity as it is less complex, but will require high levels of quality control. Let me explain: many years ago there was a heated debate as to whether the applicability of PV in remote areas should be based on micrograms or otherwise. Large projects were implemented to test which option would be more appropriate. There is a wealth of information now available that could be utilised in support of PV for Development. Solutions are site specific, however, in the opinion of many in the PV industry and NGOs, PV stand-alone systems as well as appropriately designed microgrids could be utilised as part of this activity.

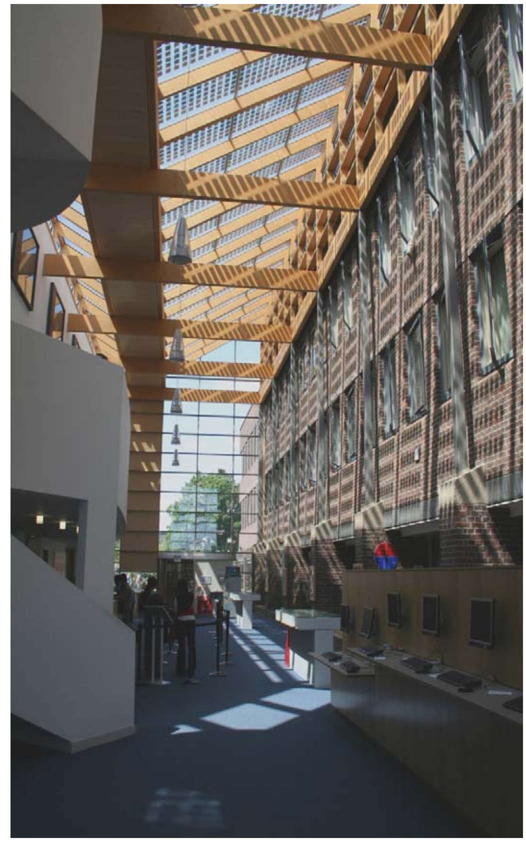


Fig. 1. A cost effective building integrated PV in an atrium at the University of Southampton, UK [7].

This article attempts to convey a new approach to establishing "PV for Development" providing electricity in rural areas around the world. It could be activated and owned by the PV industry and would likely receive global approval by many of the developed countries and international institutions.

2. Rural electrification

In many countries, the cost of extending the grid to remote communities is prohibitive due to large distance to be covered and invariably the difficult terrain to be negotiated. Small fossil fuel driver power supply systems such as diesel generators are sometimes used in remote areas. However, such a solution is not only inappropriate on environmental grounds but also due to the high cost of the fuel (also its availability), transport and maintenance requirements. Unlike fossil fuel electricity generation, the fuel in most renewable energy systems is free (sun, wind, etc.). The overall cost of a renewable energy system is totally dominated by capital and operational maintenance costs. Hence this initiative is most suited as it focuses on technology provision. For instance if we consider electricity from photovoltaics, the resource is omnipresent, and what is needed is the technology and a social and economic approach (local) for implementation, maintenance (technical training) and ownership.



Fig. 2. Rural electrification could also include water pumping, etc.

Rural electrification is best suited to what is termed stand-alone PV systems (not tied to a highly organised grid). Such systems are modular, flexible to adapt in different locations and scalable to keep pace with need. A system mainly consists of a module(s) delivering dc power and a battery governed by a charge controller. In essence, the stored energy in the battery is the main supplier of electricity to external loads such as lighting. Inverters to convert dc to ac are seldom used as they introduce further complexity [8], but in some instance stand-alone inverters can be used to power ac appliances and support microgrid applications. In addition, such systems are also suited to clean water, in which the function of the battery is replaced by the storage of the pumped water (see Fig. 2). Other professional PV systems such as those used in telecommunications and telemetry and warning systems, etc. are also classified as stand-alone systems.

Rural, here, implies remote dwellings which are far away from the grid and are unlikely to receive an electrical connection from the grid in a foreseeable future. As indicated earlier, the delivery of electricity for say lighting, to such dwellings is best served by the modular and less maintenance intensive stand-alone PV systems. However, as shown in Table 1, such systems can be envisaged to enhance the quality of life of villagers, provide connectivity to the outside world and perhaps instigate small commercial "cottage" activities within a rural setting.

Table 1
Some aspects of applicable rural electrification utilising stand-alone PV systems.

Basic needs	Lighting, potable water, refrigeration, small battery charging
Quality of life enhancements	Communication, radio, TV and video, health clinic amenities, WAN Internet, community systems for schools
Cottage industry	Mechanical system power (sewing, workshops, milling, craft activities), irrigation water pumping, refrigeration, etc.

3. PV for development—new industry-owned approach

Rural electrification has been extremely difficult to dent. For instance, as far back as the year 2001, the G8 received a commissioned report by a specially formulated Task Force on this subject [9]. The report concluded by stressing the need for action then that has at it centre the goal for an "outcome of serving up to a billion people in the next decade with renewables" The report was not adopted by the G8 but has created a momentum that many thought would deliver on the issue. However, as suggested in [10] the lack of will to address the finance issue has made this goal extremely ineffectual. More recently, at the G8 Gleneagles meeting in the UK in 2005, a similar declaration, but more specific to Africa, was made which looks likely to suffer the same fate as those previously mentioned [11].

Eight years on from G8 2001, what is needed now is a new thinking and a scheme that could spark the provision of technology and funding for rural electrification. Such a scheme must be long lasting and owned by all stakeholders. There is a wealth of information and evidence that PV for development can work and deliver the needed supply of electricity in rural areas. For instance, the highly successful EU funded projects (Sahel, Schools in South Africa, etc. [12]) provide a wealth of information on implementation, local participation and finances. An approach similar to that discussed in [13] can be used an initial strategy to fulfil the goals presented here (see Section 3.1, below).

In the view of this author, and after the major strides made by the PV industry, it is now time for this now highly developed PV industry not only to call the shots in initiating a new approach of "PV for Development" but also to challenge such entities as the G8, the UN and the World Bank. It is clear from the various meetings that the author has had with the PV industry leaders that their wish is to be socially responsible and that they are keen to support a new and more sustainable approach to achieve the goal of utilising PV for development in rural areas [14].

3.1. Mechanistic approach

At the heart of this initiative is a "*Declaration and a Commitment by the Global PV Industry to deliver annually an increasing level of PV technology for development that could at least reach 3.5 GWp by 2020*". This initiative is based on the following threads that provide an initial set up to spark a debate for implementation and governance:

(i) PV industry driven technology contribution—that should be independent, challenging and promoted proactively; and
(ii) Inducements of governments and international institutions to contribute double the declared aim of the industry. This perhaps could be achieved through negotiations at the highest levels, in the first instance within the G8 group and extended later on. The approach will be through pressure or challenge mechanisms that could be employed prior to and at the on-set of the PV industry scheme.

In order to arrive at the goal of the Declaration, the analysis has the following assumptions:

1. Market growth in 2008/2009 has achieved ∼4.0 GWp of annual production.
2. PV Industry to develop a corporate social responsibility (CSR) mechanism for PV technology options independent of governments, comprising the following:
   (a) Implement a technology contribution based on yearly manufactured output (not capacity) that will need to deliver 1 Wp/kWp (one watt per kilowatt peak) or 0.1% of production by the industry in the 1st year 2009.

(b) The contributions in (a) to be coupled with appropriate growth rates multipliers. Various options can be envisaged for this: for example contribution through equitable and taper membership classification: large industry = platinum, medium = gold, etc.
(c) Contributed technology to be owned by a "PV Industry Trust". Any Project for development can draw on this for technology implementations (this could also include contribution to balance of systems (BoS) such as batteries, etc. However, governance and procedures are to be developed later through consultation (see also Section 4.2).

3. Challenge the G8 countries to provide funds to double the industry contribution (=increase in production!). The mechanism for this is highlighted under (ii) above. In addition, as indicated before, this thread of the process has history and likely to succeed. Furthermore, in a recession laden world, such a contribution could sustain the PV industry which will undoubtedly be under pressure due to the economic upheaval around the financial sectors in the world.

4. Results and discussion

4.1. Case 1: 1.0 W/kWp for 40% growth rate

Based on the above assumptions, the projections to achieve the required goal of the Declaration are shown in Figs. 3 and 4.

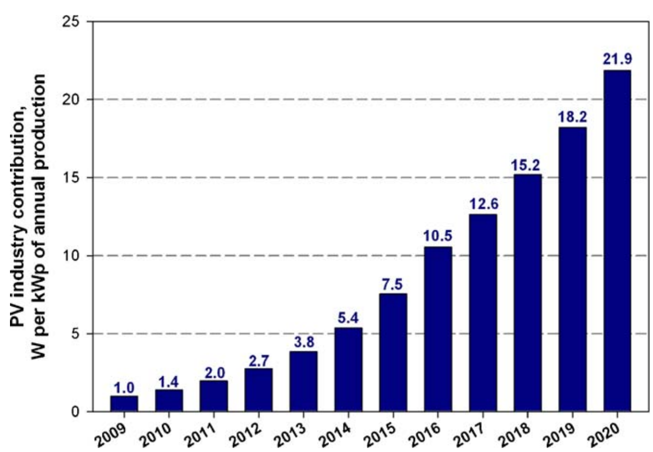


Fig. 3. Annual PV industry contribution based on W/kWp of manufactured products, starting at 1 W/kWp in 2009 and for year-on-year 40% growth rate of the industry.

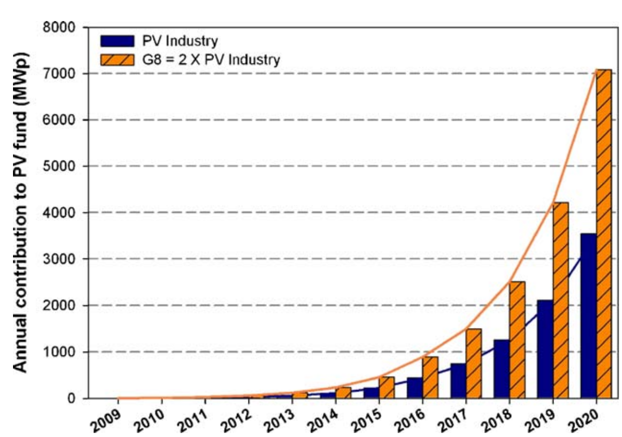


Fig. 4. Annual projections in terms of contributed MWp that could be delivered through the proposed scheme. The results show two trends that of the PV industry (Fig. 3) and G8 contribution—for the case 1: 1 W/kWp and a 40% growth rate.

In Fig. 3 the annual contribution in terms of W/kWp of manufacturer's production is depicted. This is based on a tapered approach. So that at the start and for the period 2009–2016 the growth rate is set to 40%, hence each subsequent year will see an increase of the W/kWp by the same growth rate. However, when the value of W/kWp reaches a value of approximately 10 W/kWp (2016), and for the period 2017–2020, the contribution is tapered and is half that of the growth rate or 0.05% of production at the year 2016. This is reflected in the figures for the period 2017–2020. Beyond 2020 the final contribution is proposed to be capped at an agreed figure of perhaps a quarter of the growth rate.

Fig. 4 shows the projections in terms of MWp that could be delivered year-on-year through the proposed scheme to 2020. The results show two trends. One is the contribution thorough the PV industry manufacturing of the technology and is based on the yearly growing W/kWp, shown in Fig. 3. The other trend is related to an assumed contribution from the G8 countries and perhaps other global institutions. The values used here are for year-on-year global contributions which are doubled that of the PV industry.

The outcome of this theoretical but achievable approach is as follows:

- An annually increasing contribution by industry to achieve ~3.5 GWp by 2020, based on a percentage contribution on the production by PV industry.
- An annually increasing contribution by the G8 countries to achieve ~7.0 GW by 2020. This is based on a contribution double that of the PV industry.
- Over the period of study 2009–2020, the overall cumulative contribution ~26 GWp.

Hence, for a starting contribution in 2009 of 1.0 W/kWp and a 40% growth rate, by 2020 an industry driven PV for development (supported by the G8) could cumulatively achieve approximately 26 GWp of PV that could be utilised for rural electrification.

4.2. Case 2: 1.0 W/kWp for 25% growth rate

In the current world economic climate, the "one watt per kilowatt" starting approach, coupled with a 40% growth rate may seem to some to be aggressive. However, the starting industry contribution seems to be at the right level; as some in the PV industry are already planning to contribute more than 0.1% of output.

With regards to the growth rate, and in the current economic climate, it may be advisable to be cautious. Hence it is instructive to look at a more conservative case. A growth rate that can be attained by the industry and is reasonable in this climate, seem to be around 25% for the period under study. The results of the analysis under these conditions are depicted in Figs. 5 and 6.

In Fig. 5, represent a similar approach as in Fig. 3, the annual contribution in terms of W/kWp manufacturer's production is depicted. However, this time the growth rate for the period 2009–2016 is set to 25%. In the 2016, the industry contribution is growth rate is also halved as before. This is reflected in the figures for the period 2017–2020. Beyond 2020 the final contribution is proposed to be capped at an agreed figure of perhaps a quarter of the growth rate.

Fig. 6 shows the MWp projections for the case of 25% year-on-year growth. As before, two trends are shown indicating the PV industry and the G8 countries double contributions. As can be seen from the figure, the outcome of the analysis shows expected reductions in deliverable MWp targets. However, many in the industry may feel that these targets are much more realistic and can result in tangible projects delivery around the world. The results for the revised 25% growth rate are summarised below:

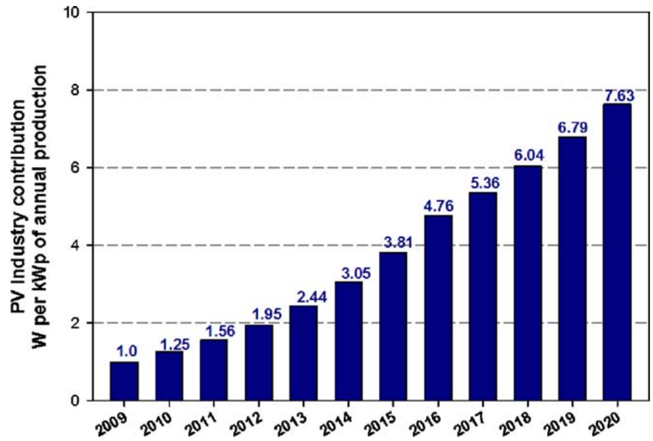


Fig. 5. Annual PV industry contribution based on W/kWp of manufactured products, starting at 1 W/kWp in 2009 and for year-on-year 25% growth rate of the industry.

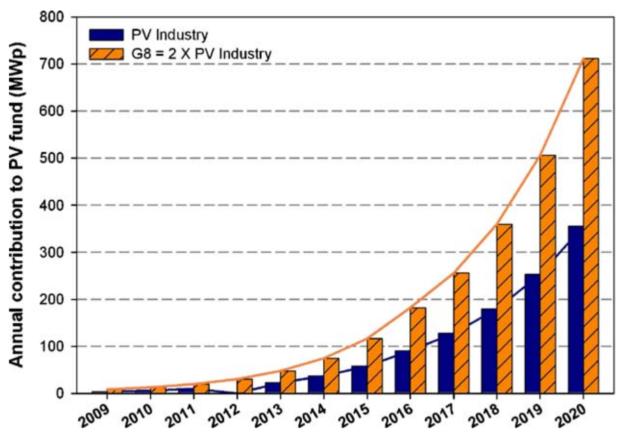


Fig. 6. Annual projections in terms of contributed MWp that could be delivered through the proposed scheme. The results show two trends that of the PV industry (Fig. 5) and G8 contribution—for the case 2: 1 W/kWp and a 25% growth rate.

- An annually increasing contribution by industry to achieve ~0.36 GWp by 2020, based on a percentage contribution on the production by industry.
- An annually increasing contribution by G8 to achieve ~0. 71 GWp by 2020. This is based on a contribution double that of the PV industry.
- Over the period of study 2009–2020, the overall cumulative contribution ~3.5 GWp.

Hence, for the reduce growth rate of 25%, by 2020 an industry driven PV for development (supported by the G8) could cumulatively achieve around 3.5 GWp of PV that could be utilised for rural electrification.

As mentioned earlier, in an era in which many of the developed countries are concentrating their efforts on the economic crisis, there is now a much more pressing need to focus our efforts on the less needy around the world. A new coherent and mechanistic approach is needed that could be utilised not only to achieve a PV industry action plan but also to exert additional global pressure to sustain it. In essence what is needed is an approach that not only challenges the PV community but is also extended to demand contributions from the major energy players such as global governments (G8), fossil fuel driven industries, pharmaceuticals and other institutions and trusts around the world. In promoting and implementing such a vision, the PV industry will not just deliver a needed development in many of the poor regions in the world, but will also serve itself through real global market expansion rather than just relying on the business generated through feed-in tariff (FIT) countries.

In addition, if this initiative is well implemented, it will provide the nucleus for exploring additional and multiple sustainable energy pathways which could be part of the solution to reduce our ever increasing emissions.

Table 2
Estimated cost to industry and support by donors at 30% premium for a range of ex-factory module cost.

Module cost (US$/Wp)	Estimated costs to industry and donors		
	2009 –2016 (10^9 US$)	2016–2020 (10^9 US$)	Total (10^9 US$)
Industry cost spread			
1	0.19	0.38	0.57
2	0.38	0.76	1.14
3	0.57	1.14	1.71
Donors paid to industry			
1.3	0.50	0.99	1.49
2.6	0.99	1.98	2.97
3.9	1.49	2.97	4.46

4.3. How much will it cost?

Table 2 gives the estimated costs for the two periods discussed in Section 3.1. It depicts (a) the PV industry contribution as a function of ex-factory cost for three scenarios of 1, 2, and 3 US$/Wp; and (b) the support by donors at 30% premium for the range of ex-factory module costs. The data for the two periods for 1.0 W/kWp manufactured contribution and double that from the G8 for 40% growth rate is also shown in more detail in Fig. 7. The trends show the impact of the year-on-year growth rate on the estimated costs and for the all the scenarios of manufacturing costs and premiums on these from G8 contributions.

If one aims for a more realistic figure of 2 US$/Wp of ex-factory cost, at a "donor" premium to industry of 30%, the total support for PV for Development will be US$ 4.11 billion over 12 years (or per annum US$ 0.34 billion). This is made up of US$1.14 billion from industry and US$ 2.97 billion from donors delivering approximately 26 GWp of electricity generation. Obviously, the ex-factory cost will also change over the years but such analysis is worthwhile to give a feel for the likely costs. Note that if we halve the contribution from the PV industry to say 0.5 Wp/kWp manufactured, all the

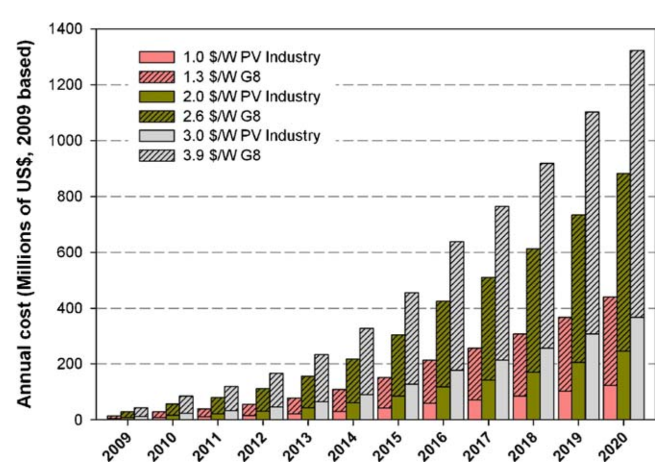


Fig. 7. Estimated costs for the two periods for 1.0 W/kWp manufactured contribution and double that from the G8—for the case 1: 1 W/kWp and a 40% growth rate.

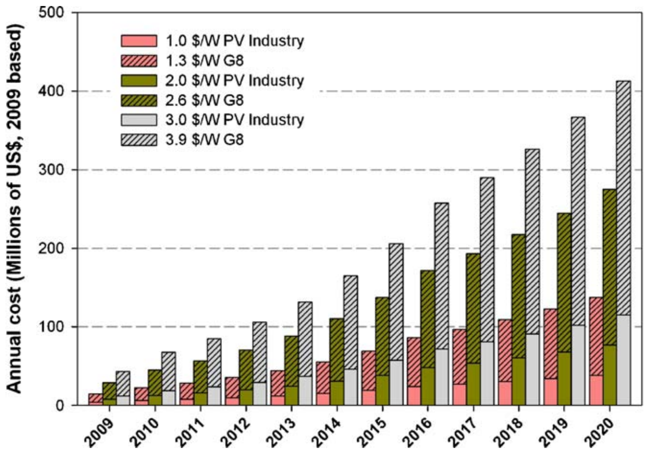


Fig. 8. Estimated costs for the two periods for 1.0 W/kWp manufactured contribution and double that from the G8—for the case 2: 1 W/kWp and a 25% growth rate.

contribution figures are also halved. Obviously the annual contribution is tapered as per Fig. 4 and hence the annual contribution will start at a lower level allowing the nurturing of the process and ramping up in the later years.

Fig. 8 shows the cost profile for the conservative growth rate of 25%. Again, at a 2 US$/Wp of ex-factory cost, and a "donor" premium to industry of 30%, the total support for PV for Development will be in the region of US$ 1.64 billion over 12 years (or per annum US$ 0.136 billion). This is made up of US$0.45 billion from industry and US$ 1.64 billion from donors delivering approximately 3.5 GWp of electricity generation. These figures are perhaps much more realistic as they more than likely to succeed. By starting the process at a lower scale of contributions will facilitate time to gear up the process and the development of projects as a manageable scale.

4.4. Open ideas for implementation

What we need now is a new game plan that will address the implementation of this scheme. The following steps could provide the initial inception process of such an initiative:

- PV industry to form a working group to agree the process, procedures and acceptable level of technology support. In essence a Trust could be formed that could provide the needed governance of the initiative. Governess could be modelled or perhaps use global infrastructure as the Red Cross, Oxfam and some elements of the UN programmes.
- The EU, World Bank, UN to be targeted to join this initiative. Such entities have their own programme much more akin to what this initiative is endeavouring to achieve.
- Then we need to bring in the G8. There is currently an on-going approach to re-activate the previous intentions. An industry initiative of this magnitude is more than likely to speed up the process and deliver tangible support to rural electrification.

In addition, such a plan must take into account sustainability issues (social, environmental and economic), so that project implementations are sensitive to existing indigenous local activities, be it commercial or otherwise. In other words, any scheme should be socially responsible and efficiently executed. Ideas on these will need further development through a consultation process with stakeholders and project implementers.

Overall, the above activities will need to be accountable to the PV community. Fora should be held at appropriate international PV conferences, donor meetings in which status reports are given, targets set and reviewed.

5. Summary and conclusions

This article promotes a new joined-up approach linking developed and developing countries, global institutions, as well as the PV industry and NGOs. The idea of a link to the global aid programmes (countries, EU, etc.) and those addressing the alleviation of poverty (World Bank, UN) has been highlighted previously [13]. This will be an extremely worthwhile approach that could provide the necessary impetus to achieve the G8 contribution to this proposed scheme.

The major points for this initiative are highlighted below:

- These initial ideas could be developed further and owned by the global PV industry to use PV to support development where needed.
- The additional aim of this initiative is to put pressure on governments and institutions to generate appropriate actions (multiples of PV industry contributions). This will result in an increase in production and hence further expansion of the industry.
- Industry can select to deliver technology or funding at market prices.
- The taper or capping can be reviewed after 2015 but should not be lower than, say 20%. The question here is this appropriate or enough?
- Contribution could also be solicited from other institutions, for example: The Welcome Trust, Pharmaceutical industry, Microsoft Foundation, Banks, etc.

The result is an industry driven technology contribution that could result in at least 3.5 GWp of PV by the industry only that could be used for development by 2020.

This initial analysis indicates that such an approach is achievable providing that the PV industry are honest, candid and they have the will to realise the call of "PV for Development". Furthermore, if this approach is 'too painful', it is extremely easy to arrive at lower figures by reducing the W/kWp to say 0.5 W/kWp of production in the first period, ramping up at say 2015 to 1 W/kWp produced.

We now need to be ambitious and set the necessary targets to achieve at least a dent in the required level of rural electrification. This is not just an environmental vision to develop de-carbonised power systems but is a social imperative for the development of the less fortunate around the world.

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